Computer Vision – Cloud, Smart or Both

University of Sussex

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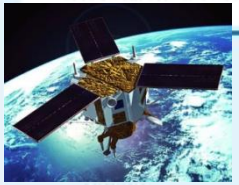
University of Sussex

COGS seminars Summer 2012

Tuesday 22nd May – 16:00 – 17:30
Arts C133

Management and Protection

- OTN fault isolation
- Protection switching
- Easy-to-use network management software



Long-Haul DWDM

Cell Backhaul

CWDM

Metro DWDM, ROADM, OADM

High Capacity

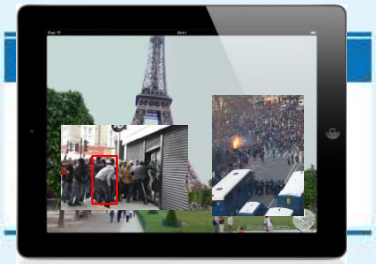
- Up to 80 channels
- Up to 10 Gb/s
- 40 Gb/s migration
- Muxponding/Aggregation

Access CWDM

CWDM

WDM

Voice/Data/ Video

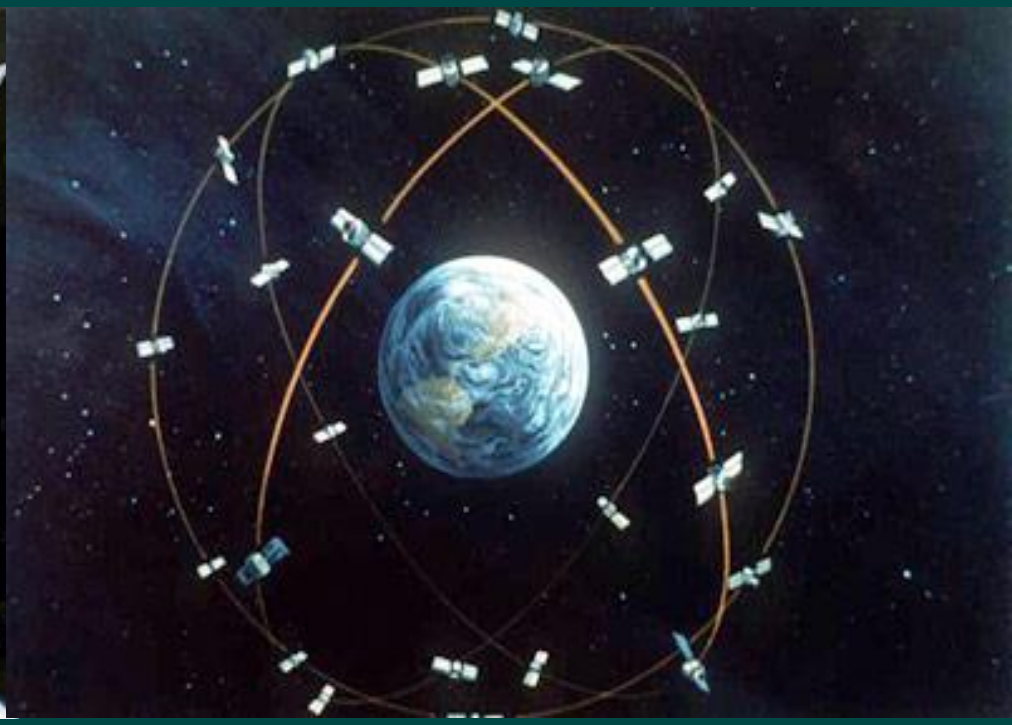


Wavelength Services

Transparent

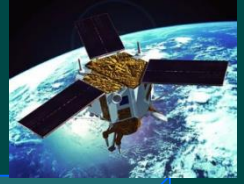
- Ethernet, GbE, 10 GbE
- SONET/SDH
- Legacy - PDH
- ESCON, FICON, Fibre Channel
- Video

A Important Element of Security System - Global Positioning System



- 24 spacecraft in 12 hour circular orbits, with 3 on-orbit spares. Six circular orbital planes, R=26,560km
- All users with clear view of sky see the minimum of 4, but usually see 6-8



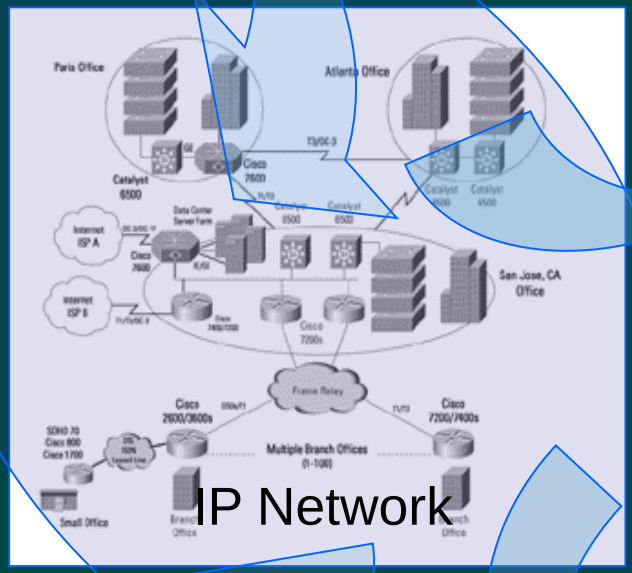


Urban Surveillance

Smart IP Cameras
mapped into 3D space

Alerts & Meta Data

IP address, Time stamp, GPS location, Alarm type



IP Network

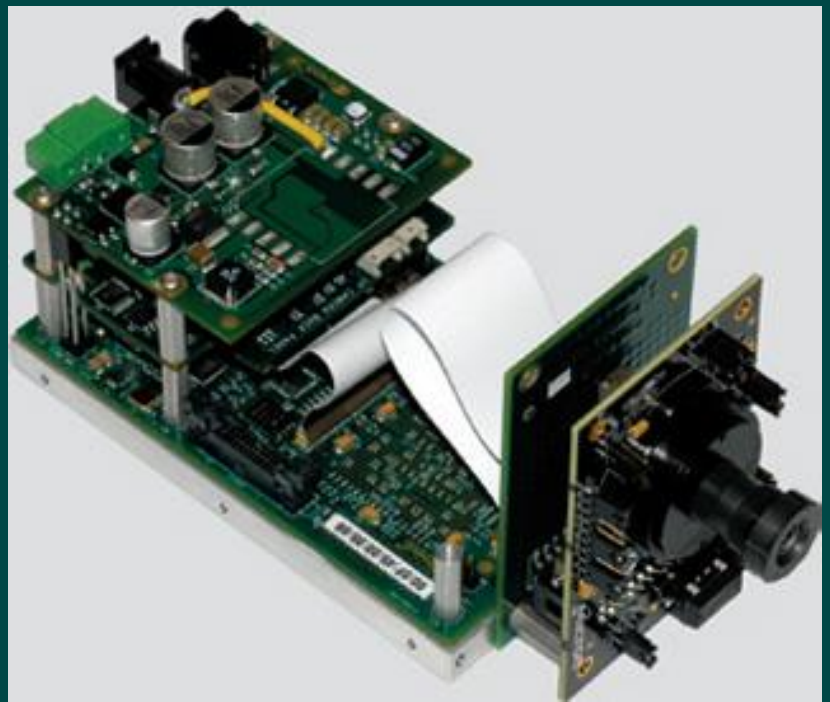
Data & Meta-
Data Storage

Responders

Smart Camera’s

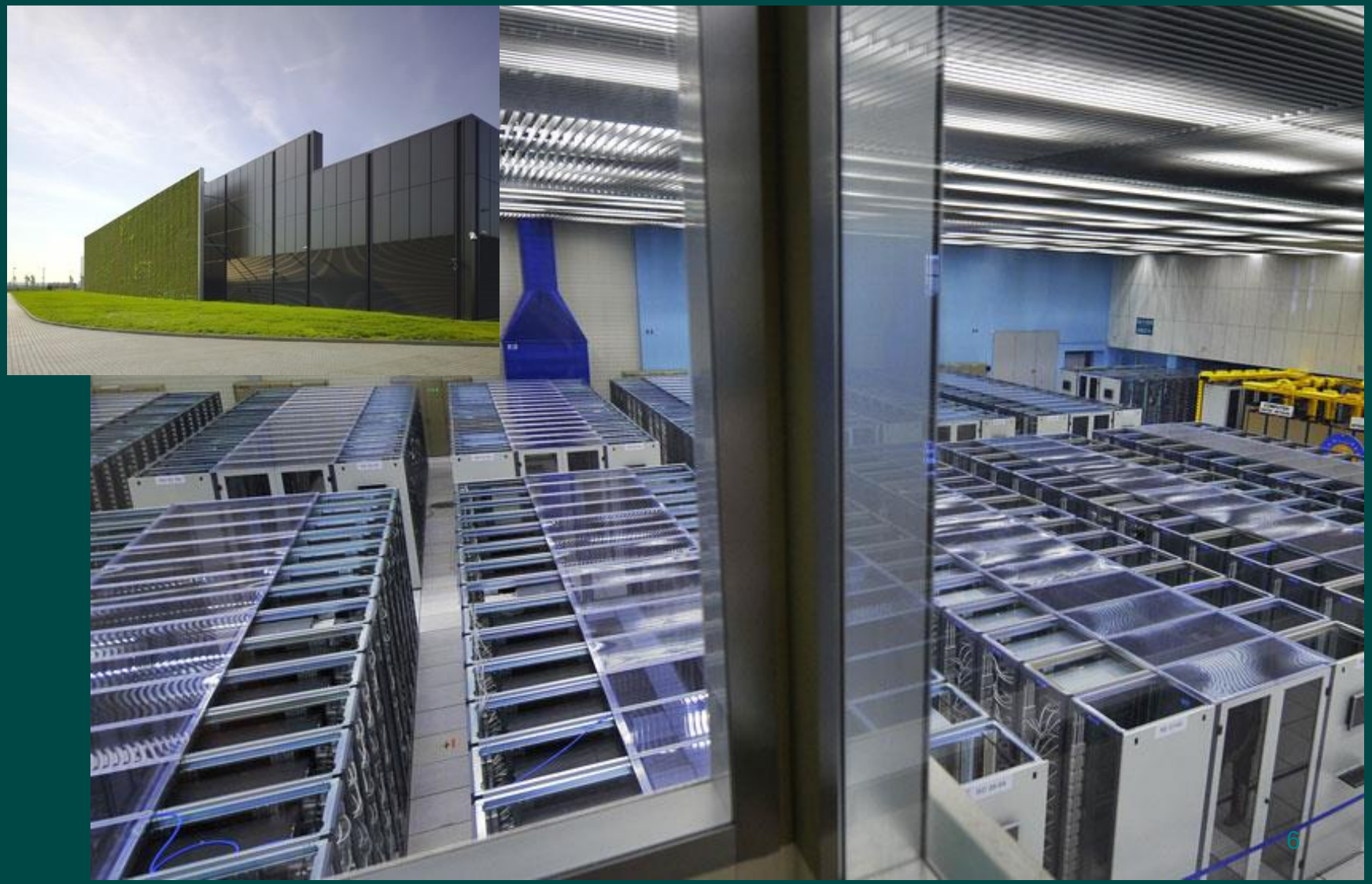
IP-camera-based single-chip system S6105 company Stretch c processor Xtensa LX, a network adapter 10/100 Mbs, CMOS-Sensor 2 MP, H264

Texas Instruments DaVinci DSP frequency from 594 to 729 MHz. Network adapter 10/100/1000 Mbs, CMOS-sensor 2 MP, H264

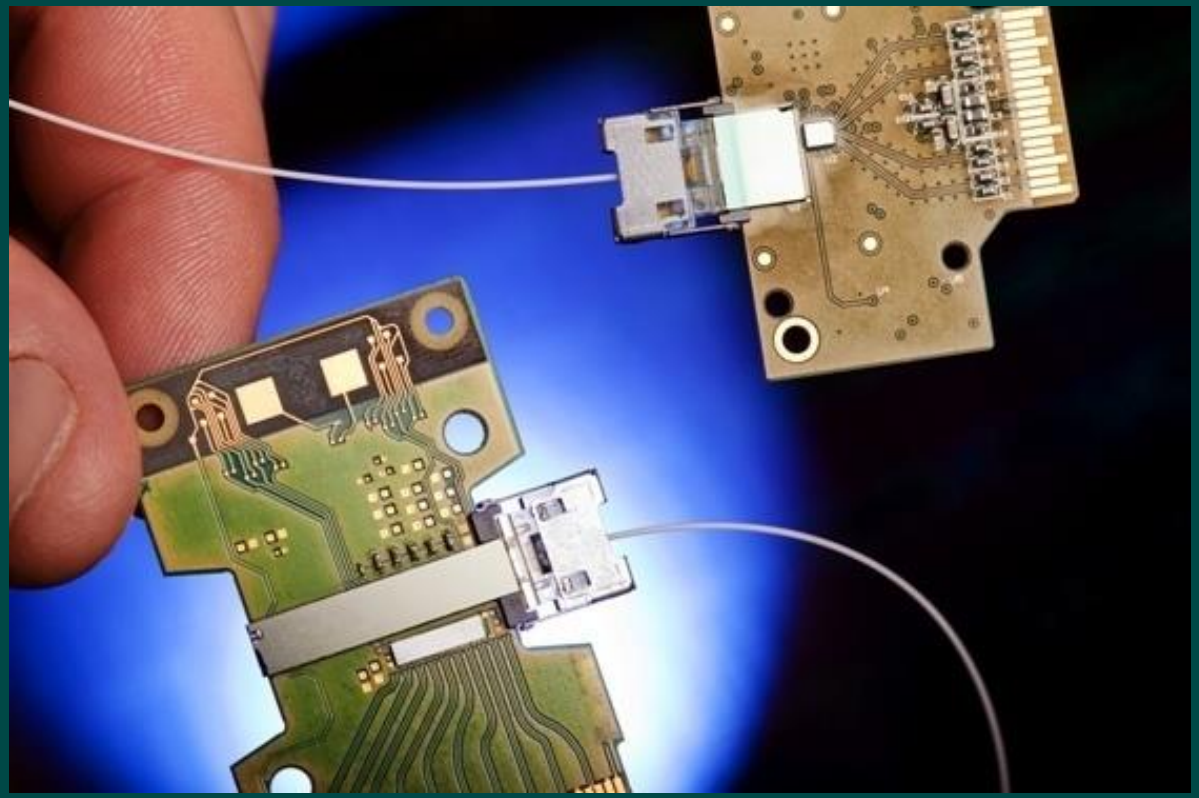


Essential meta data:
IP address, Time stamp, GPS location, Alarm type

Datacentres – Bandwidth Management for the Cloud

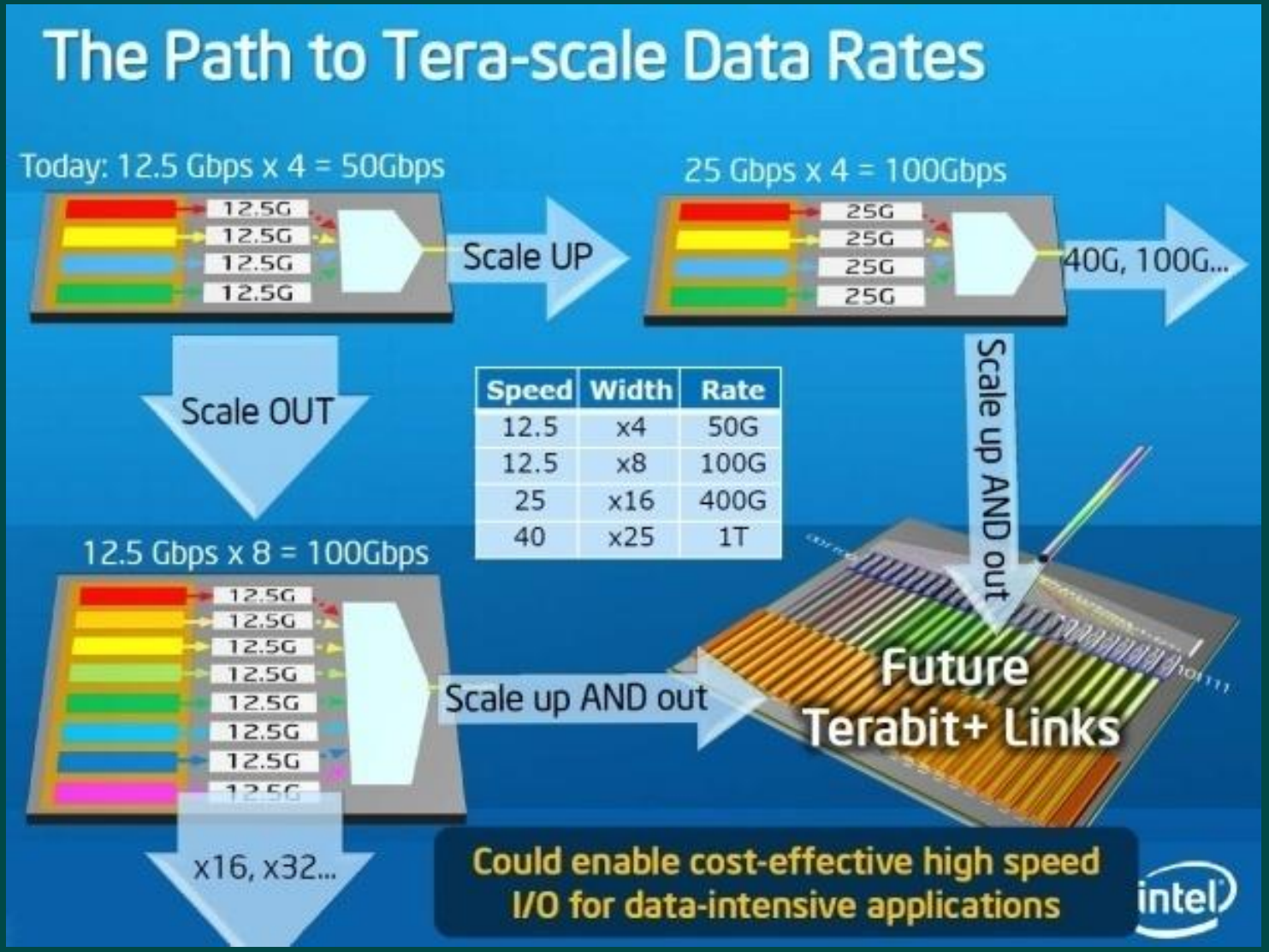


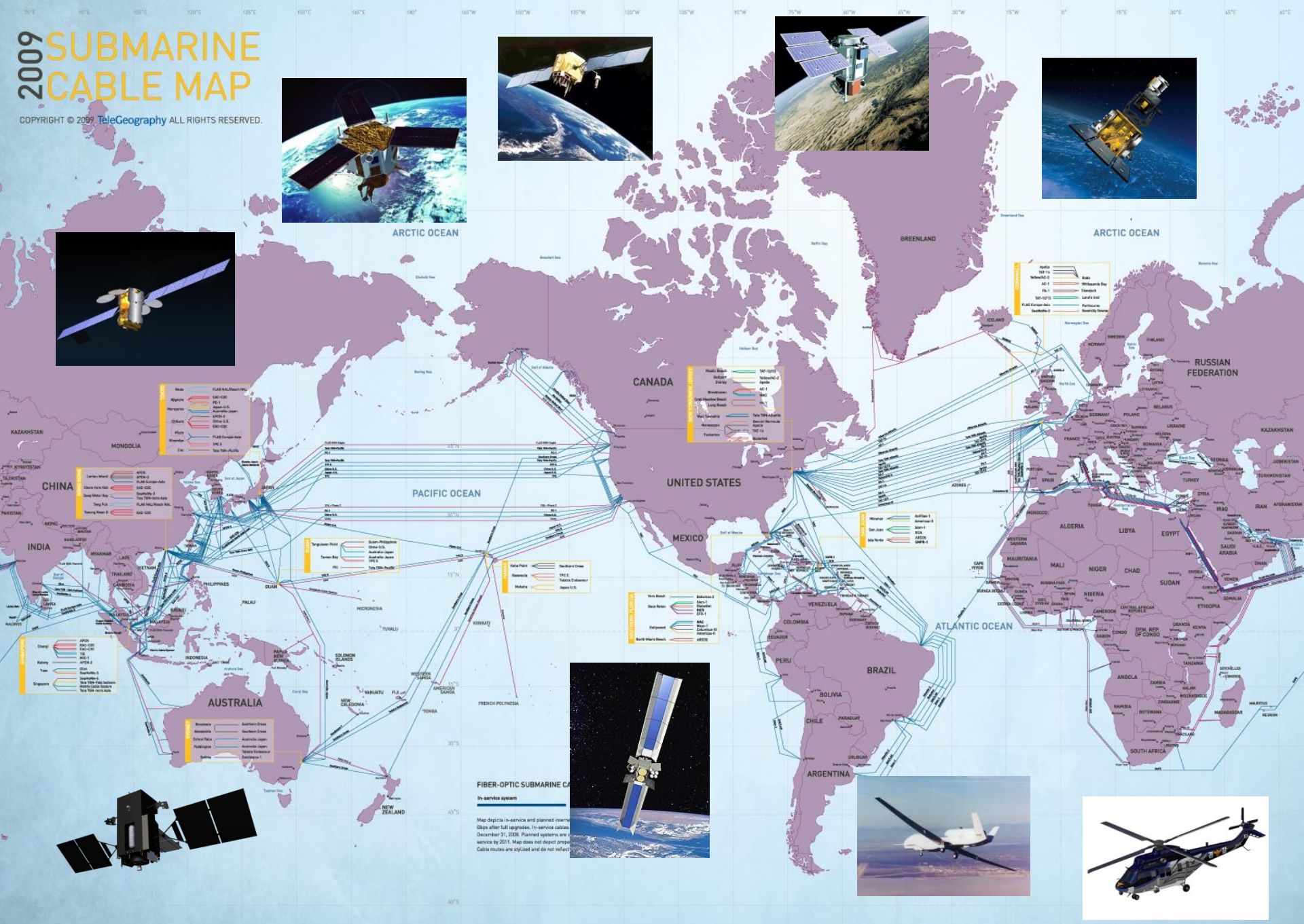
Intel's 50Gbps silicon laser transmitter, at bottom left, and optical receiver, at top right



Intel has debuted the prototype of a high-speed fibre optic data system based on silicon chips with integrated lasers and detectors, it will revolutionise affordable data communications across IT

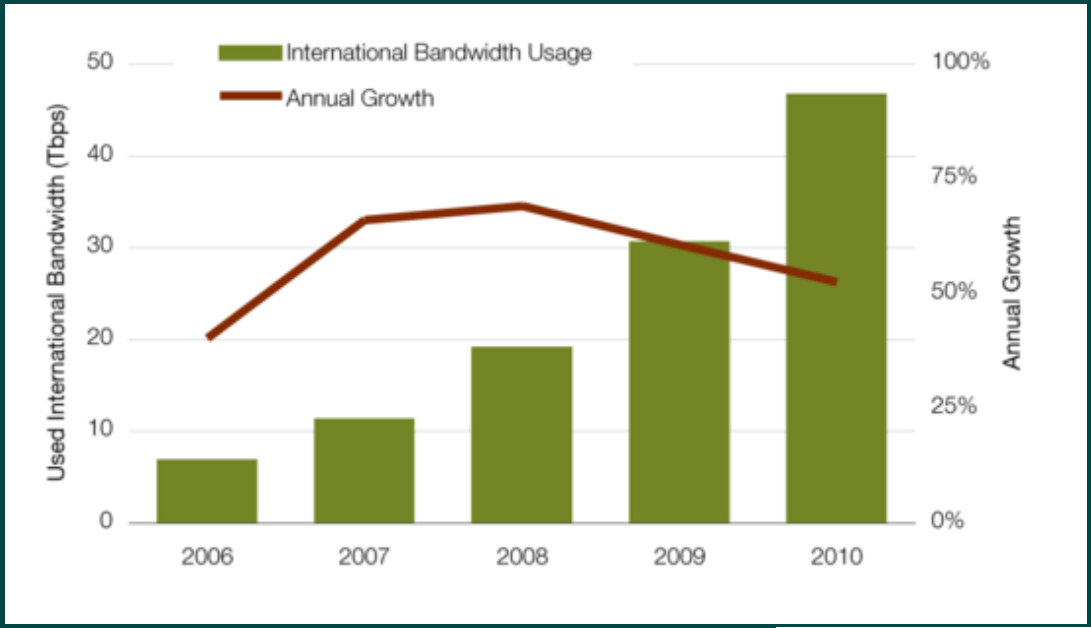
Terabit data rates

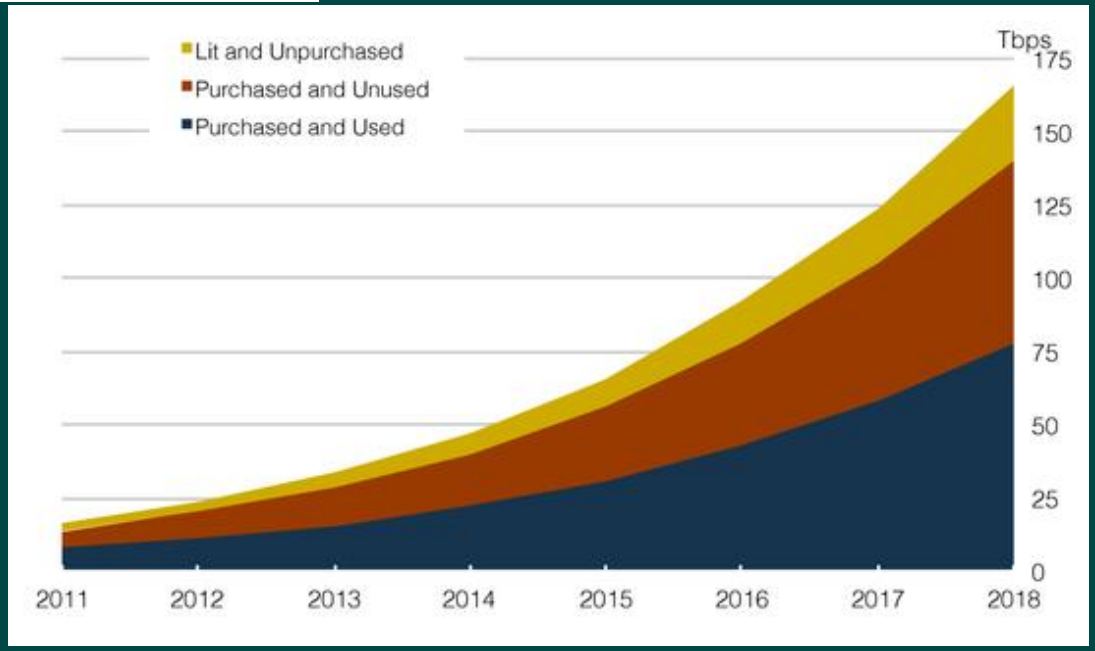




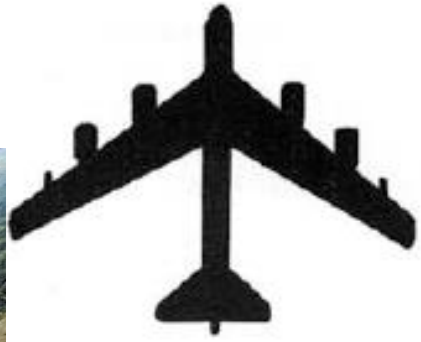
Global Data Integration Technology

Use of the Global Fibre Network

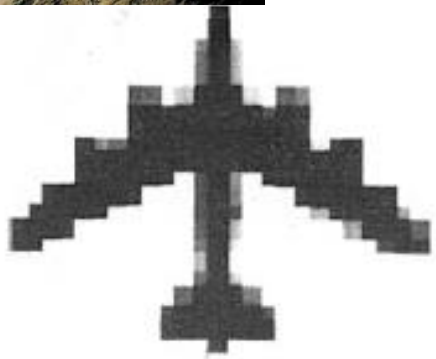


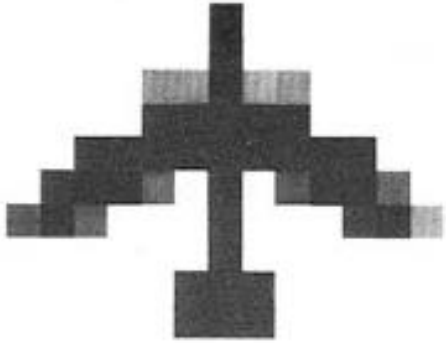


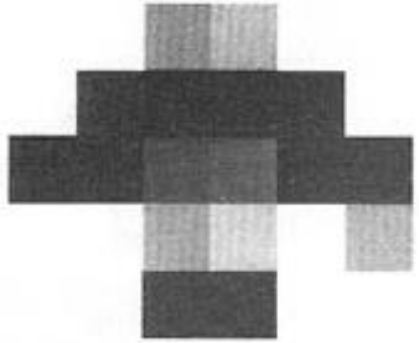
What resolution is needed


ORIGINAL


1 METRE SAMPLE


2.5 METRE SAMPLE

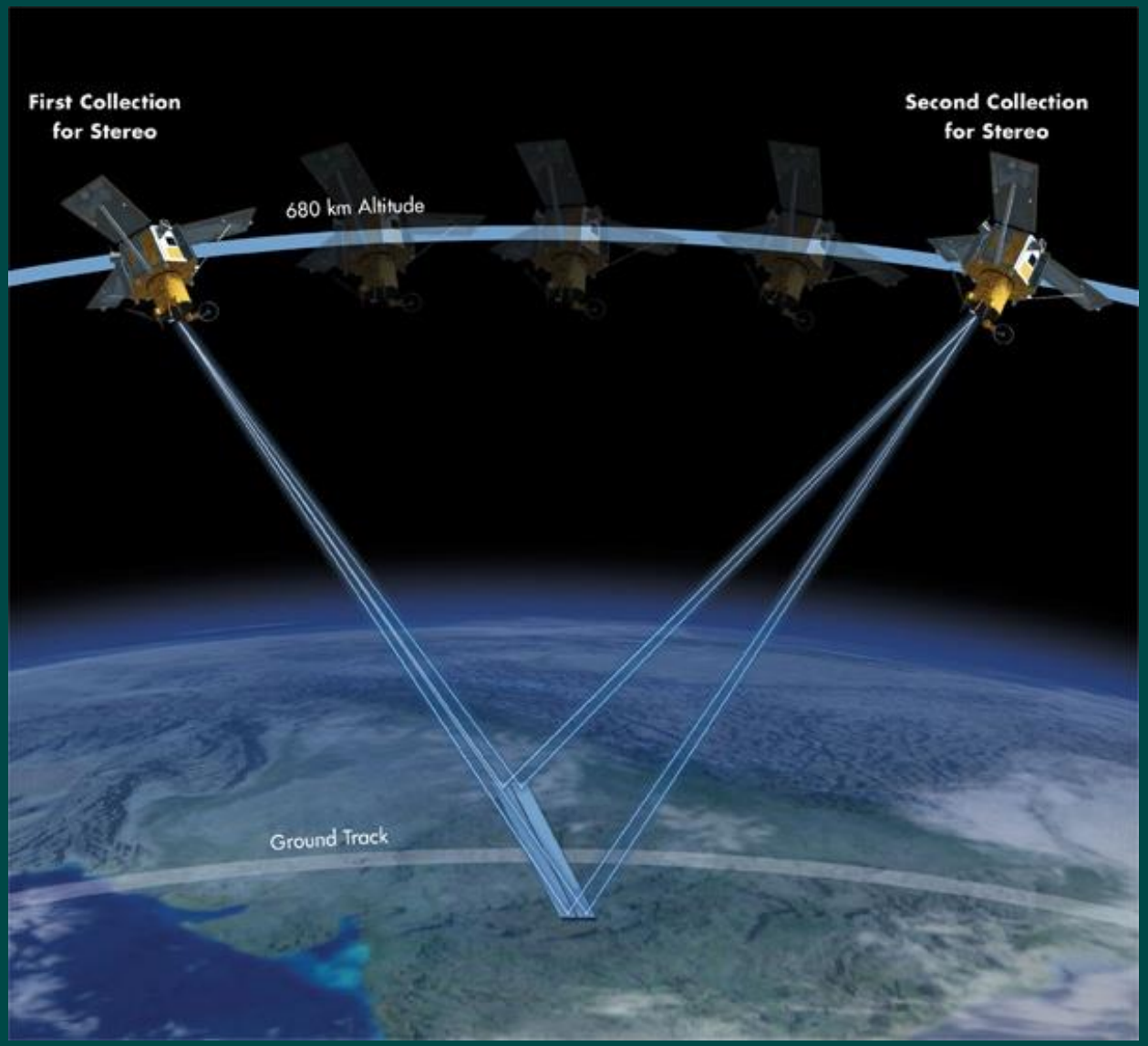

5.0 METRE SAMPLE


10 METRE SAMPLE

Source: B. Jasani and G. Stein, *Commercial Satellite Imagery. A Tactic in Nuclear Weapon Deterrence*, Springer, 2002

IKONOS Stereo Satellite Imagery
Multispectral Blue, Green, Red, and NIR.

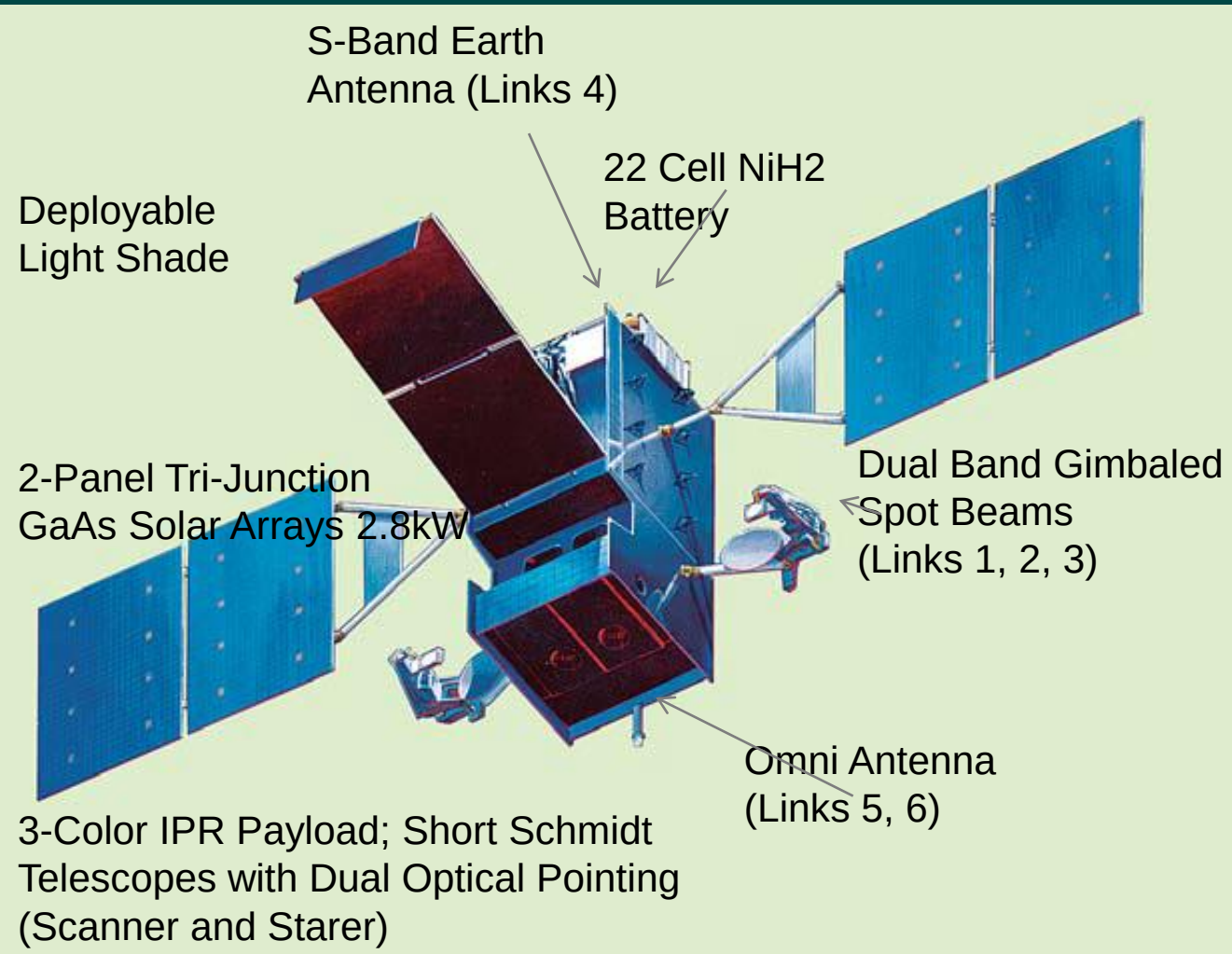
With Ground Control Points (GCP's) - <0.25m GCP accuracy standards for X, Y, Z



Quickbird, 450 km LEO, 98˚, sun-synchronous inclination, 60 cm resolution

Multispectral:
Blue: 450 - 520 nanometers
Green: 520 - 600 nanometers
Red: 630 - 690 nanometers
Near-IR: 760 - 900 nanometers

Space Based Infrared Systems (SBIRS)
12 year design life



Link Band Function

1-S down Ka Survivable mission data

1-T down Ka Normal mission data

2 up QHF Anti-jam commanding

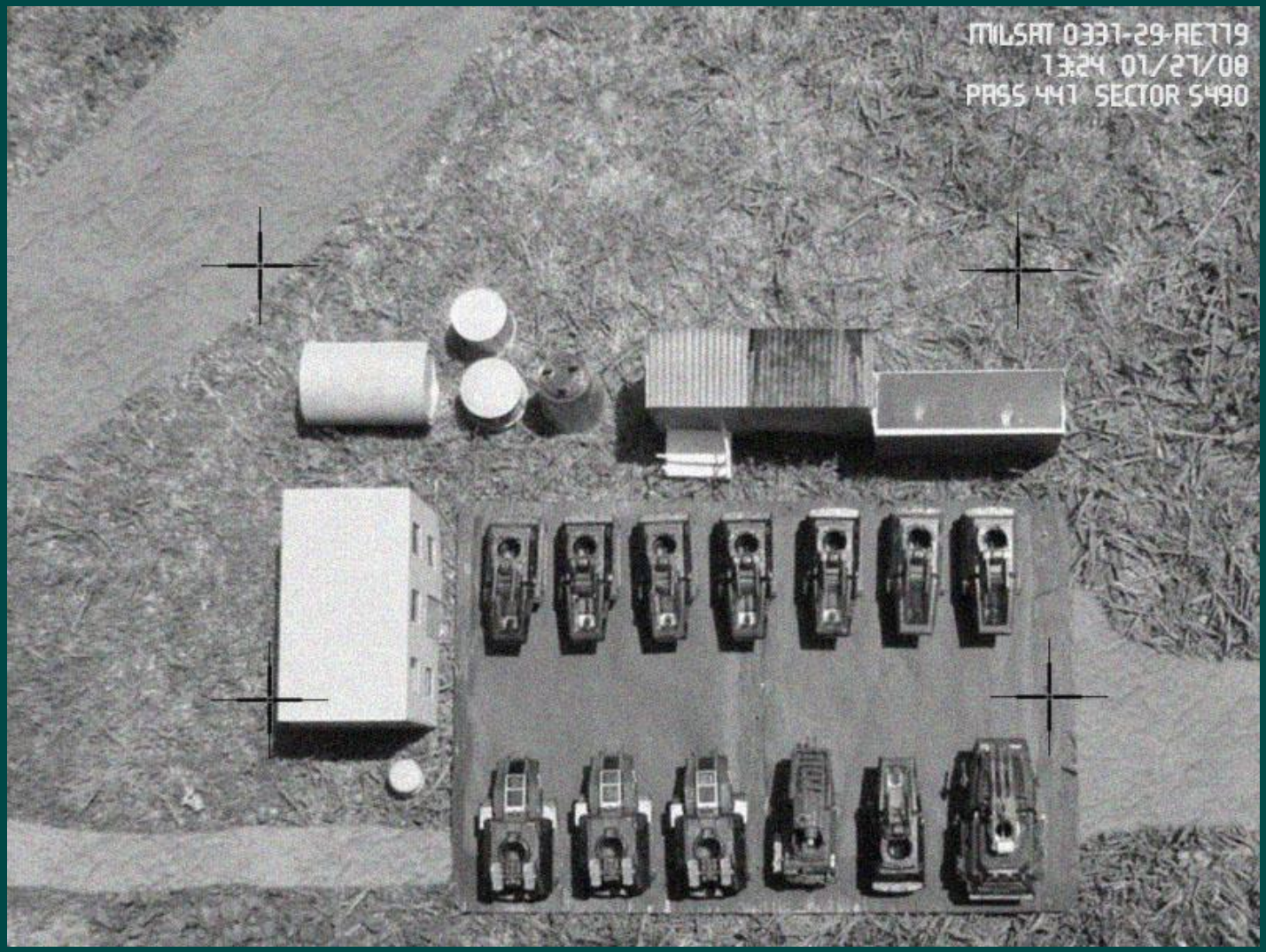
3 down Ka Wideband sensor data

4 down S Theater mission downlink

5 down S Backup SGLS telemetry downlink

6 up S Backup SGLS commanding

Satellite Image of Military Vehicles



Global Hawk High-Altitude, Long-Endurance, Unmanned Reconnaissance Aircraft, USA

Performance:
Maximum Endurance: 42 hours
Loiter Velocity = 343kt
Maximum Altitude: 65,000ft
Communications:
Satellite Comms Datalink
1.5Mbps, 8.67Mbps, 20Mbps, 30Mbps, 40Mbps, 47.9Mbps
Line of Sight (LOS) Datalink
137Mbps

Synthetic Aperture Radar (SAR) - 1m/0.3m resolution (WAS / Spot)
Moving Target Indicator - 4kt minimum detectable velocity
Electro-Optical - NIIRS 5.5 / 6.5 (WAS/Spot)
Infrared - NIIRS 5.0 / 6.0 (WAS/Spot)

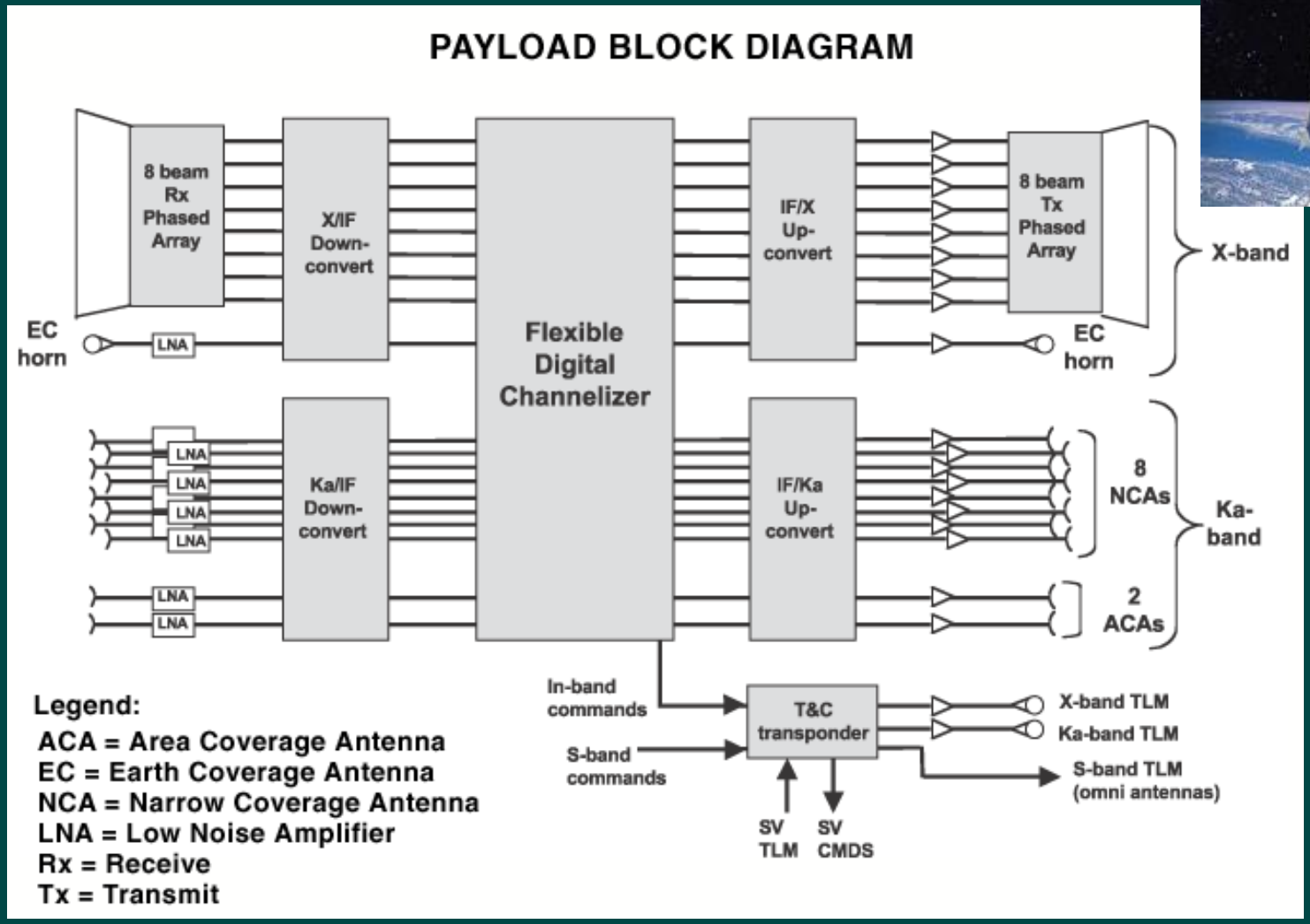
Visible & Infrared

Wideband Global Satcom (WGS) - Ka Band video transmit and receive – 4.8GHz Bandwidth

- The WGS design includes 19 independent coverage areas – 10 Ka-band and 8 X-band spot beams can be positioned anywhere in the field of view of each satellite.

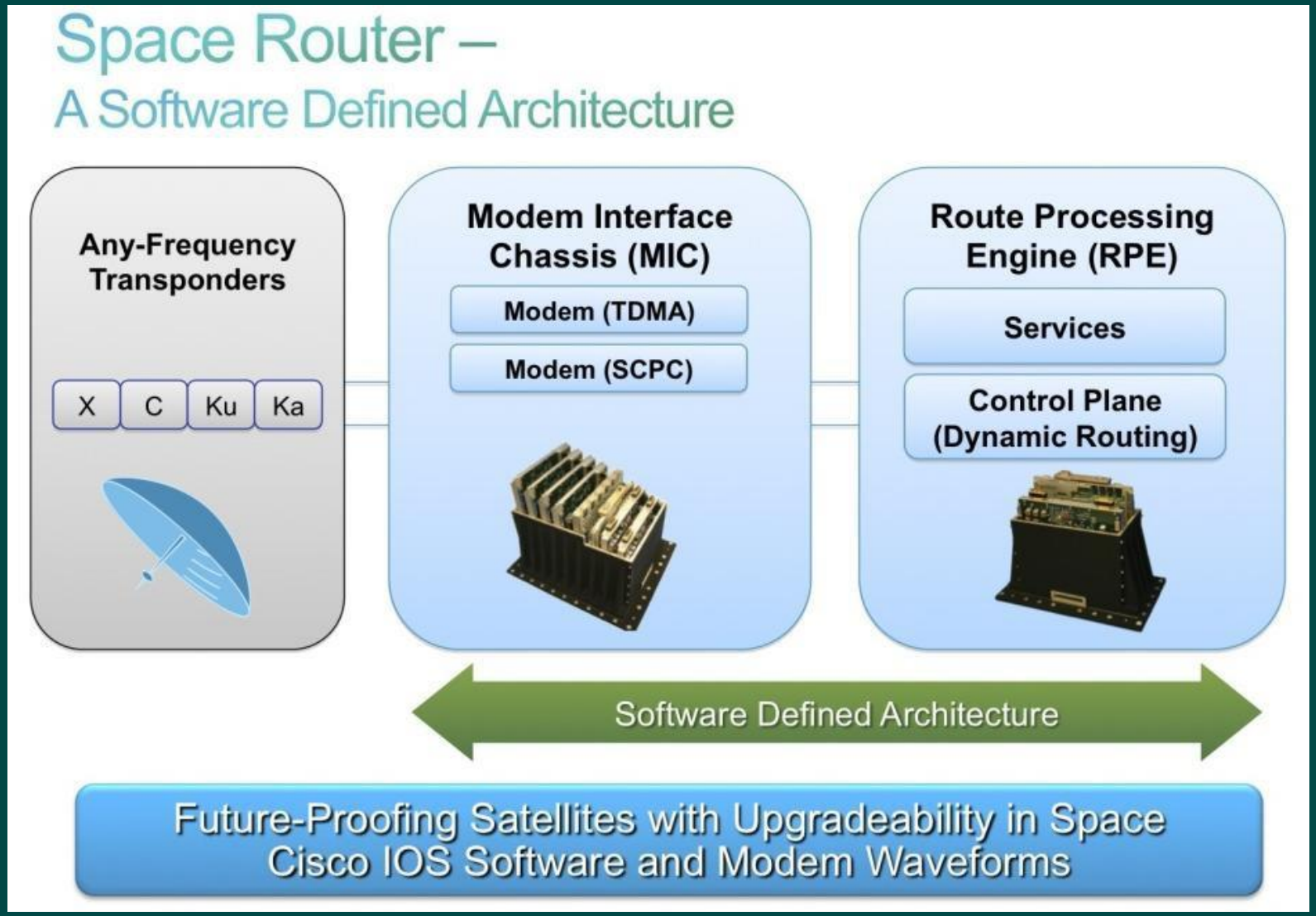
- Full-Earth coverage in X-band is also provided. Use of phased array technology allows the eight X-band beams to be steered and shaped to apply gain and power exactly where it’s needed.

On board router - 1,900 independently routable sub-channels

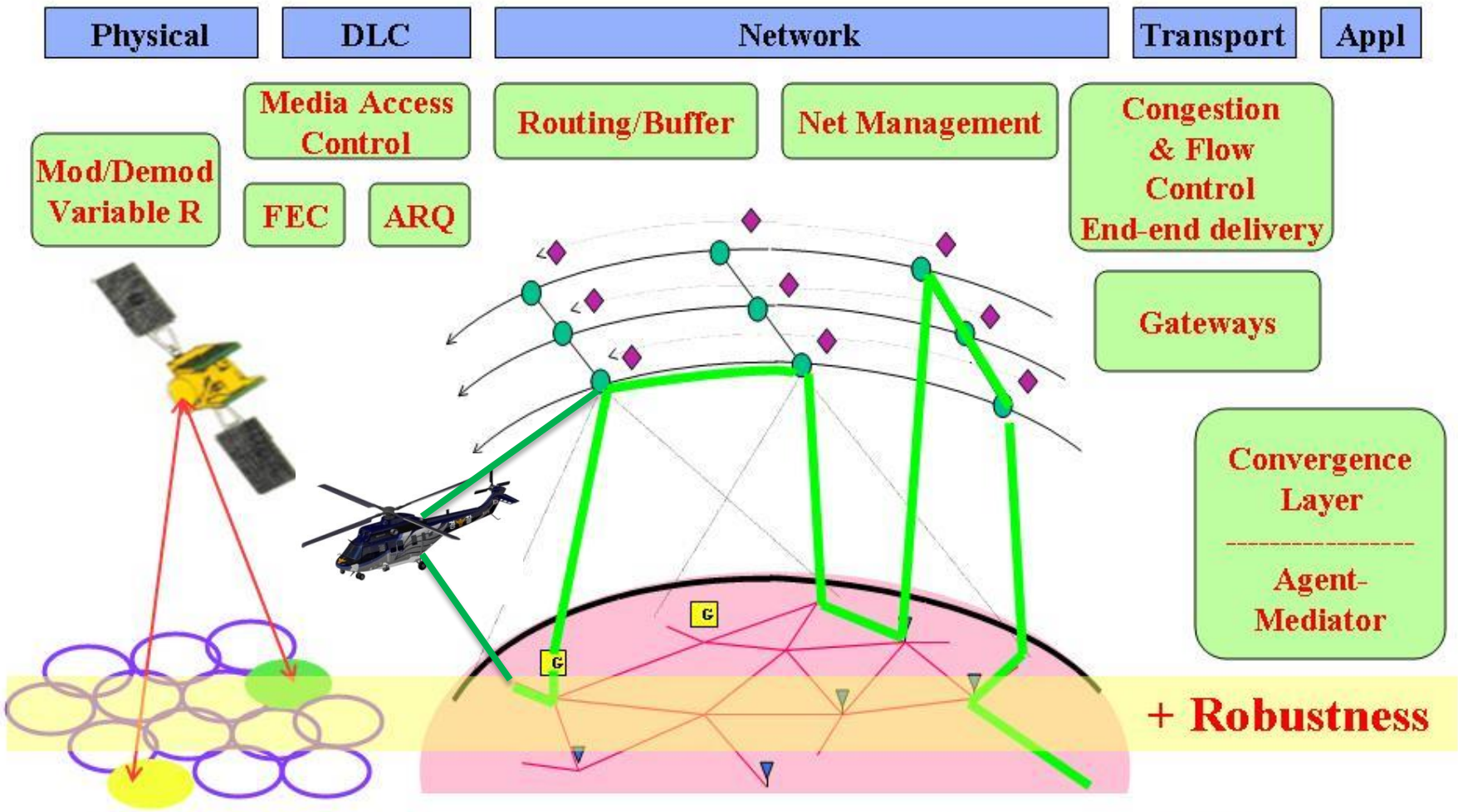


Any uplink coverage area to any downlink coverage area

Internet Routing in Space (IRIS) Payload Architecture



Satellite Networks

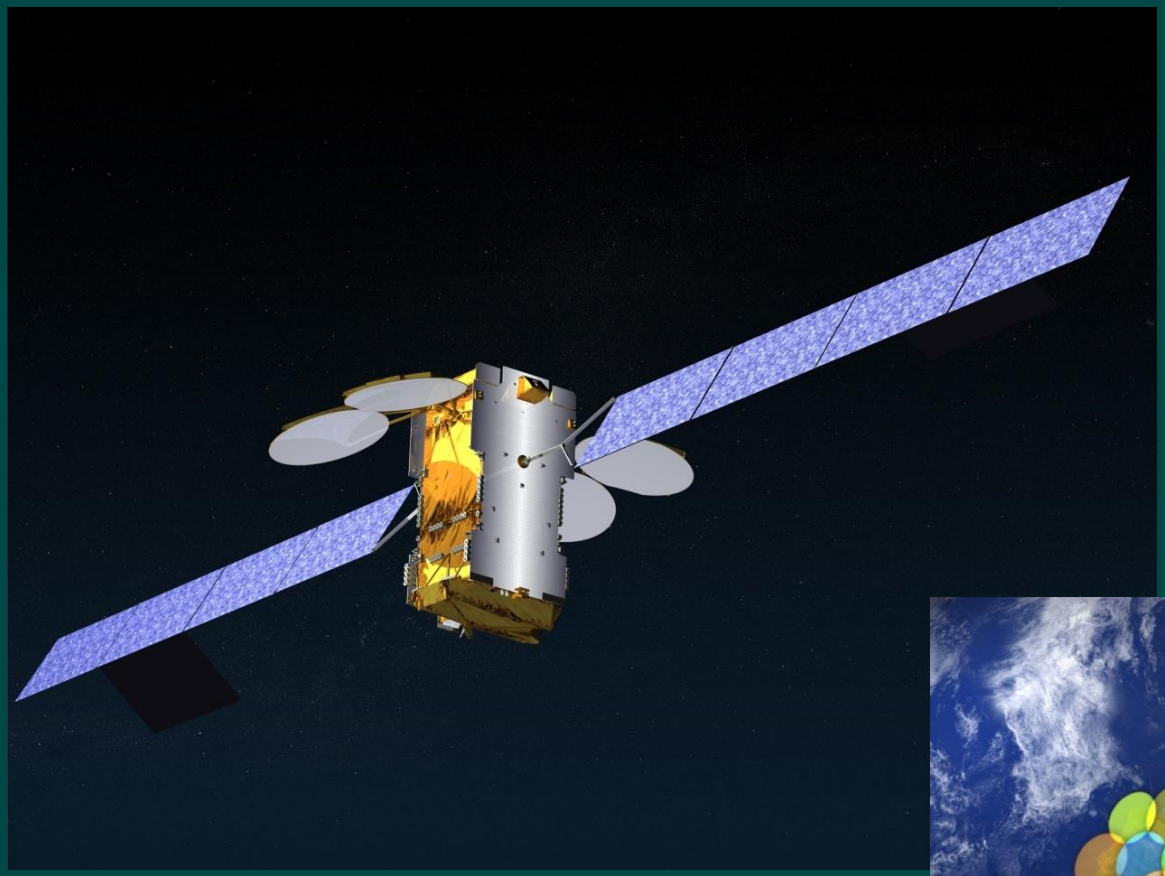


- *Dynamic Capacity*
- *Agile beams*
- *MAC*
- *Fading*

- ***Dynamic routing:*** *deterministic & stochastic*
- ***Heterogeneous network:*** *Satcom, fiber, wireless*
- ***Differentiated services:*** *policy-based, time-deadline, .*

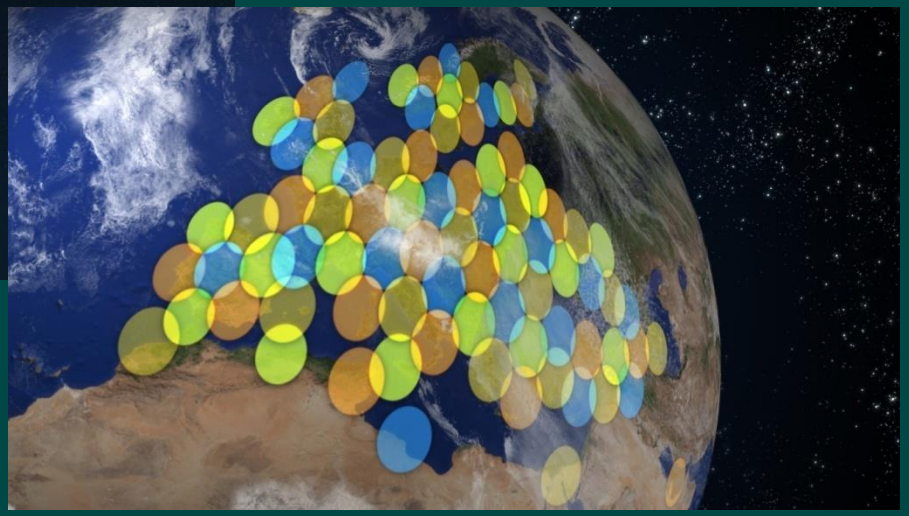
- ***Satellite resources extremely precious***

EADS Astrium Ka-SAT, 6.1 Tonnes at launch, 15 year lifetime, 11 kW



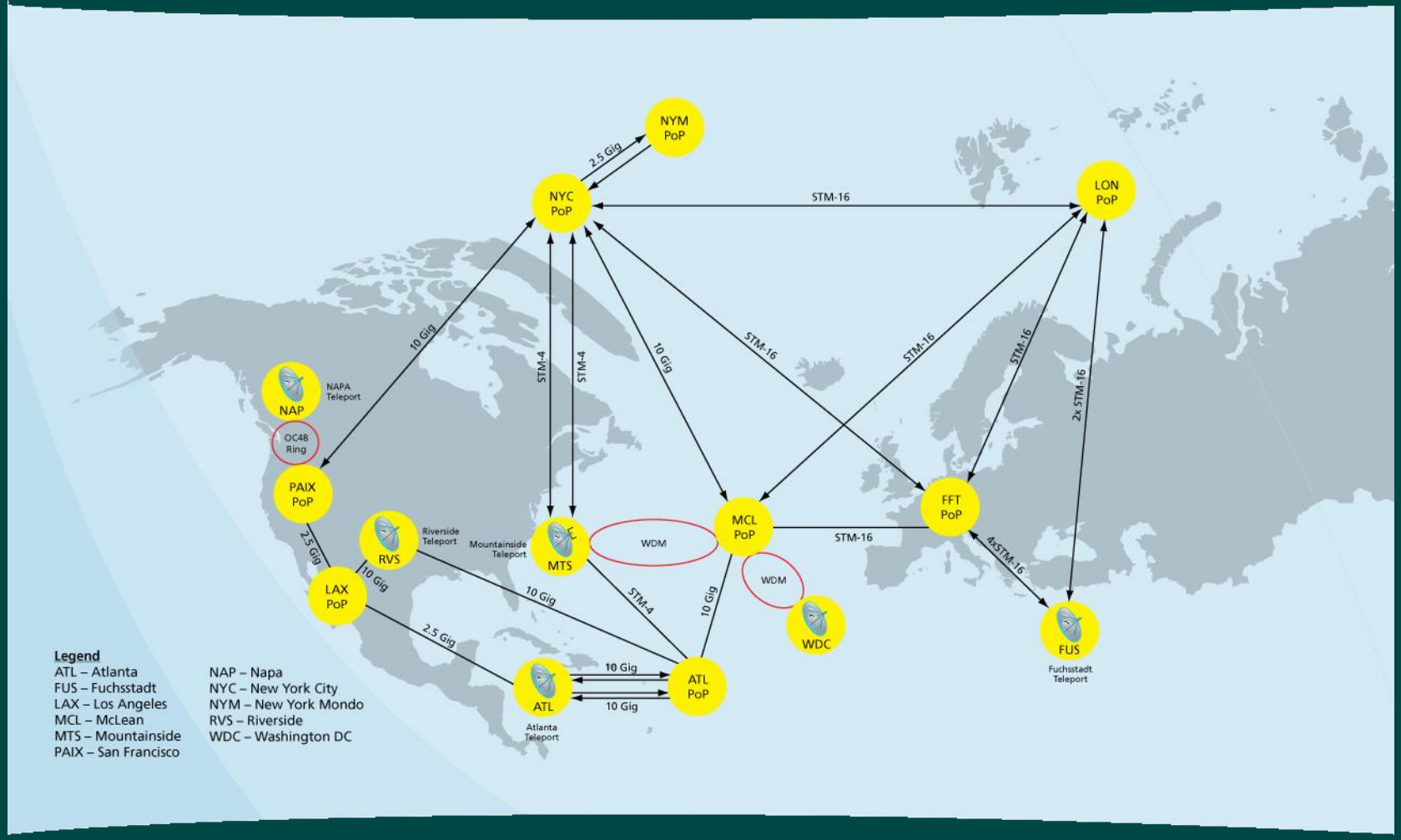
Eutelsat's Ka-SAT has a total capacity of more than 70 Gbps, 35 times the throughput of traditional Ku-band satellites.

ViaSat-1 US 100 Gbps



KA-SAT will provide ubiquitous complete coverage of Europe and the Mediterranean Basin through its 82 spot beams in Ka-band

Intelsat GXS® Fiber Network



Data Communication Evolution Impacts Computing Strategy

- Bandwidth management and availability is going to improve greatly
- The Cloud will become increasingly important for security and computer vision
- Integration of Satellite, Fibre, Wireless
- Impacts where you do the Computer Vision

Video Rate Object Detection and Tracking

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- How can we locate that object within an image
- We assume 6 degrees of freedom
  - Position x & y
  - Scale (z)
  - In-plane rotation
  - Out of plane rotation (roll and pitch)
  - 2 degree increments in three rotation axes is 540 images
  - At 3 different scales 1620 images

Pragmatic Data Reduction Strategy

- Select an image object and use it to make the filter
- The reference image is rotated -6 to +6 degrees and 7 reference images are created (2 deg increments)
- The reference images are scaled for three different scales and triple filter function bank computed.
- This is just 21 images

Clutter & Noise

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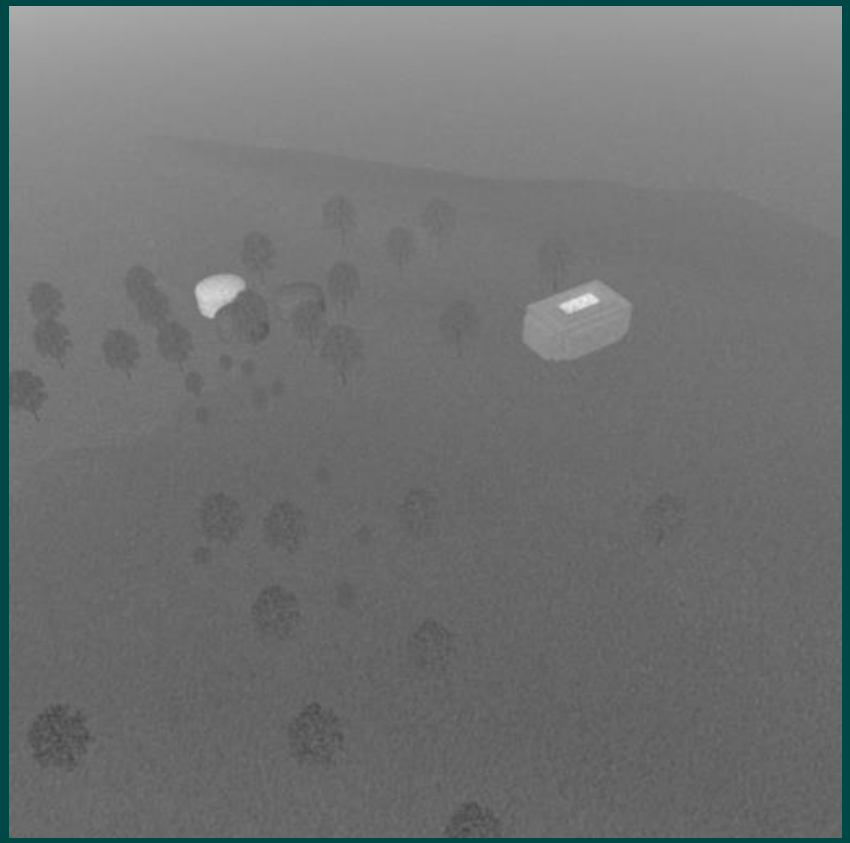
- In addition lots of image clutter
- If we assume the images are in thermal IR
- Clutter involves thermal sources (hot objects), foliage, buildings, additional vehicles



OT-MACH Filter

Frequency domain Optimal Trade-off Maximum Average Correlation Height (OT-MACH) filter function

- OT-MACH tunable nature gives :
  - ability to produce easily detected correlation peaks
  - tolerance to untrained target object distortions
  - ability to suppress noise/clutter

Fourier plane transfer function - OT-MACH

- Frequency domain Optimal Trade-off Maximum Average Correlation Height (OT-MACH) filter function:

$$h = \frac{m_x^*}{\alpha C + \beta D_x + \gamma S_x}$$

  - α, β and γ are the OT-MACH (non-negative) parameters, need to be tuned
  - m^* conjugate mean training set spectrum
  - C is the background clutter power spectral density
  - D_x is the mean power spectral density of the training images
  - S_x is the similarity spectrum of the training images
  - Typical values of α, β and γ are: 0.9; 0.8; 0.1

Pre-filter Band Pass

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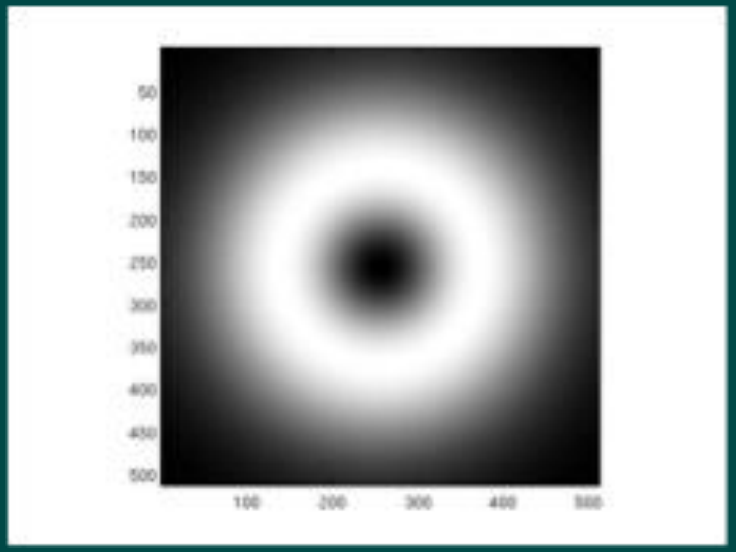
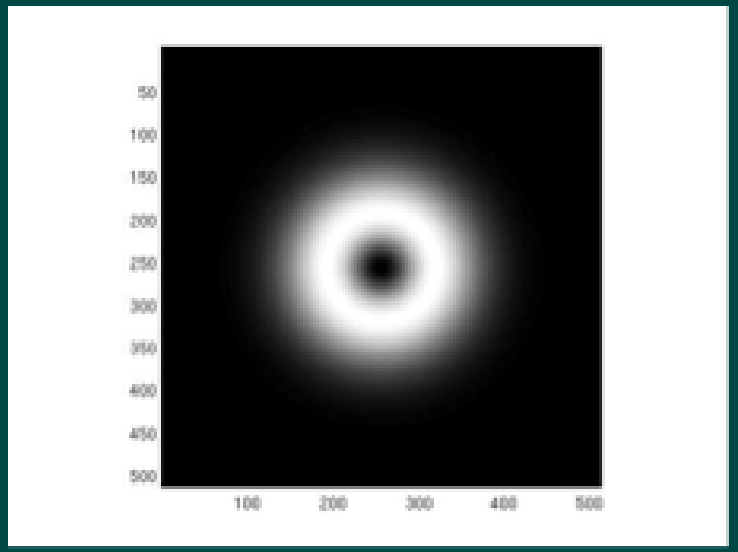
- Morlet wavelet pre-filtering ensures best features are kept
- Low frequencies are removed: copes with lighting variation & bright structures





Tracking

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- User selects object
- Algorithms tracks it
  - Must cope with
    - Scale
    - Rotation
    - Occlusions
    - Lighting
    - Clutter
    - Noise

The OT-MACH Tracker - Features

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- Performs in real-time on both colour (visible) and infra-red band scenarios.
- Conveniently trainable for real-time target tracking applications.
- Dynamic filter updatability making the algorithm robust for tracking.

Filter Initialisation

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- User interface developed for selecting a target in run-time
- Three types of user selection designed and tested
  - Rectangular
  - Circular
  - Assisted active contour
- Rectangular and Circular target selection found to be less accurate compared to active contour based selection
- The filter function is developed for three different scales of the target after scaling the selected target.

Target selection methods

Rectangular

Circular

Active Contour

Active Contour Target Reference

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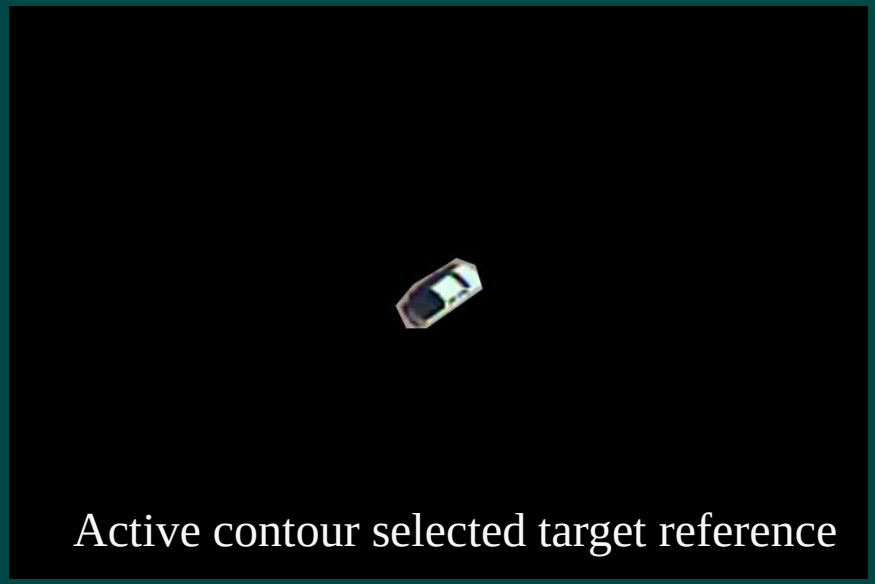
- Active contour selected target used to create a blank background reference image
- The reference image is rotated -6 to +6 degrees and 7 reference images are created (2 deg increments)
- The reference images are scaled for three different scales and triple filter function bank computed.
- A rotationally multiplexed OT-MACH filter is then created using the reference image sets.



Active contour selected target reference

Real-time implementation of the OT-MACH tracker

- After Morlet filtering, rotated reference target images are multiplexed together.
- This is Fourier Transformed to create frequency domain filter function
- The Morlet filtered, Fourier transformed input frames, are multiplied by the frequency domain filter function based on the correlation frames frequency (m), selected by the user
- The filter function is applied to every m^{th} Morlet filtered input frame to generate a correlation plane output
- We used m=5 for visible and m=2 for IR

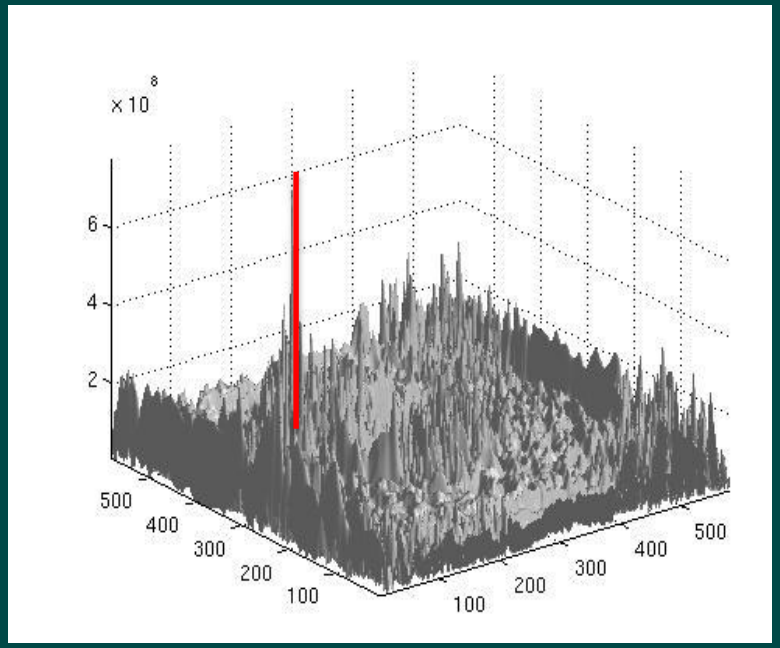
Real-time implementation of the OT-MACH tracker

- The filter is automatically updated selecting the current target every update interval set by the end-user (we did this every 25 frames for visible, every 5 frames for IR)
- Rotational multiplexing and triple filter bank increases tolerance of the filter to changes in target orientation and scale changes
- The maximum correlation height values are used to estimate if a filter update is possible or not in the next update interval
- A threshold of 85% of the maximum height value is used to locate the target

Example result and correlation plot

Cross-hair on object

Correlation plot



Kalman filter limitations

- Unlike the OT-MACH tracker, the Kalman filter method is not a suitable estimator for noisy frames, varying velocity targets and extreme scale changes

- A colour based particle filter method was also investigated and compared with the OT-MACH tracker

Kalman filter to distinguish between target and non-targets

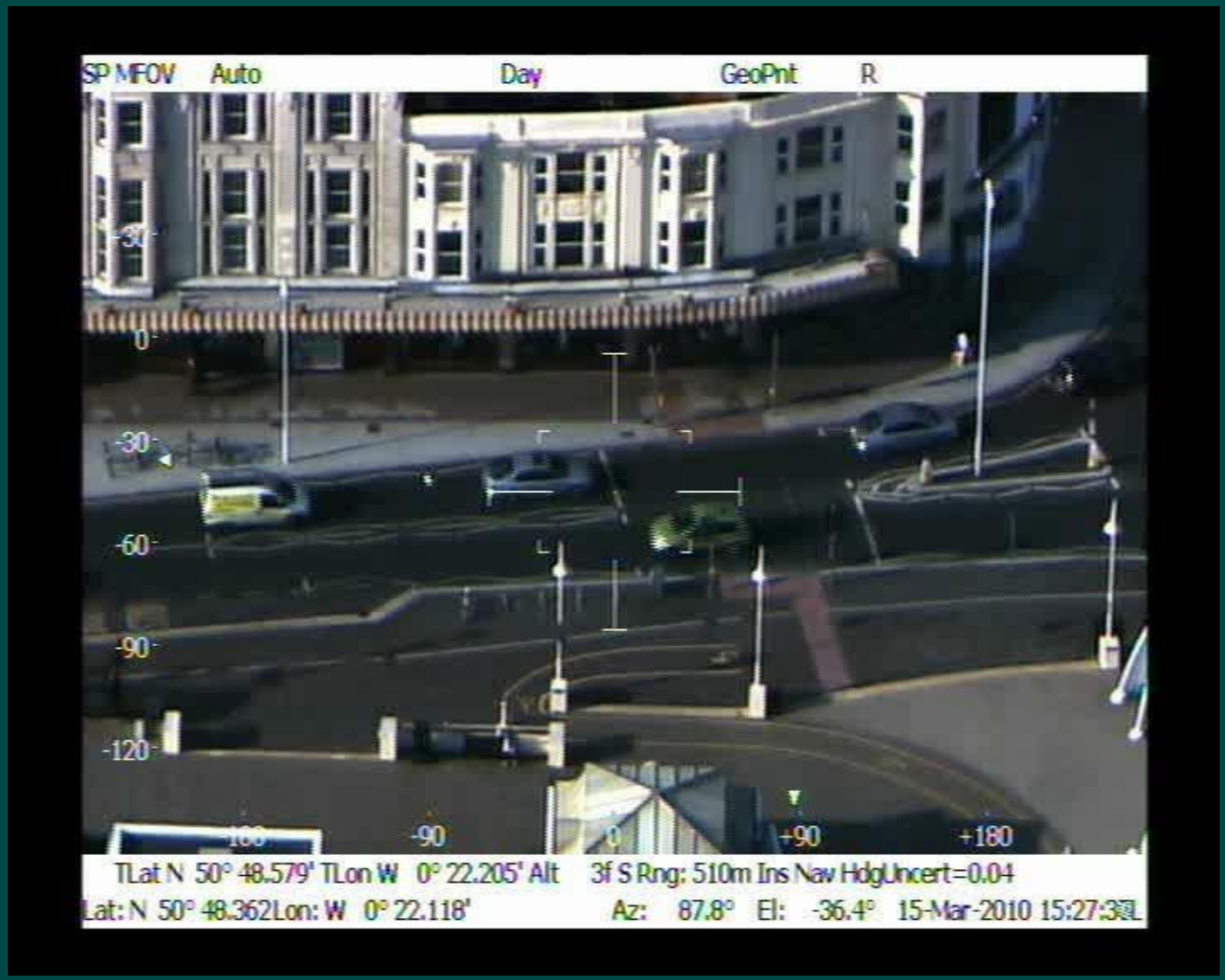
Kalman filter(red) and OT-MACH tracker(yellow) result

Colour based Particle filter to distinguish between target and non-targets

Particle filter(blue particles and red tracking) and OT-MACH tracker(yellow) result

OT-MACH tracker results

Several video sequences have been used to test the Tracker and the results are found to be accurate, hence, proving the efficiency of the tracker



OT-MACH tracker results

IR Video Result

OT-MACH tracker results

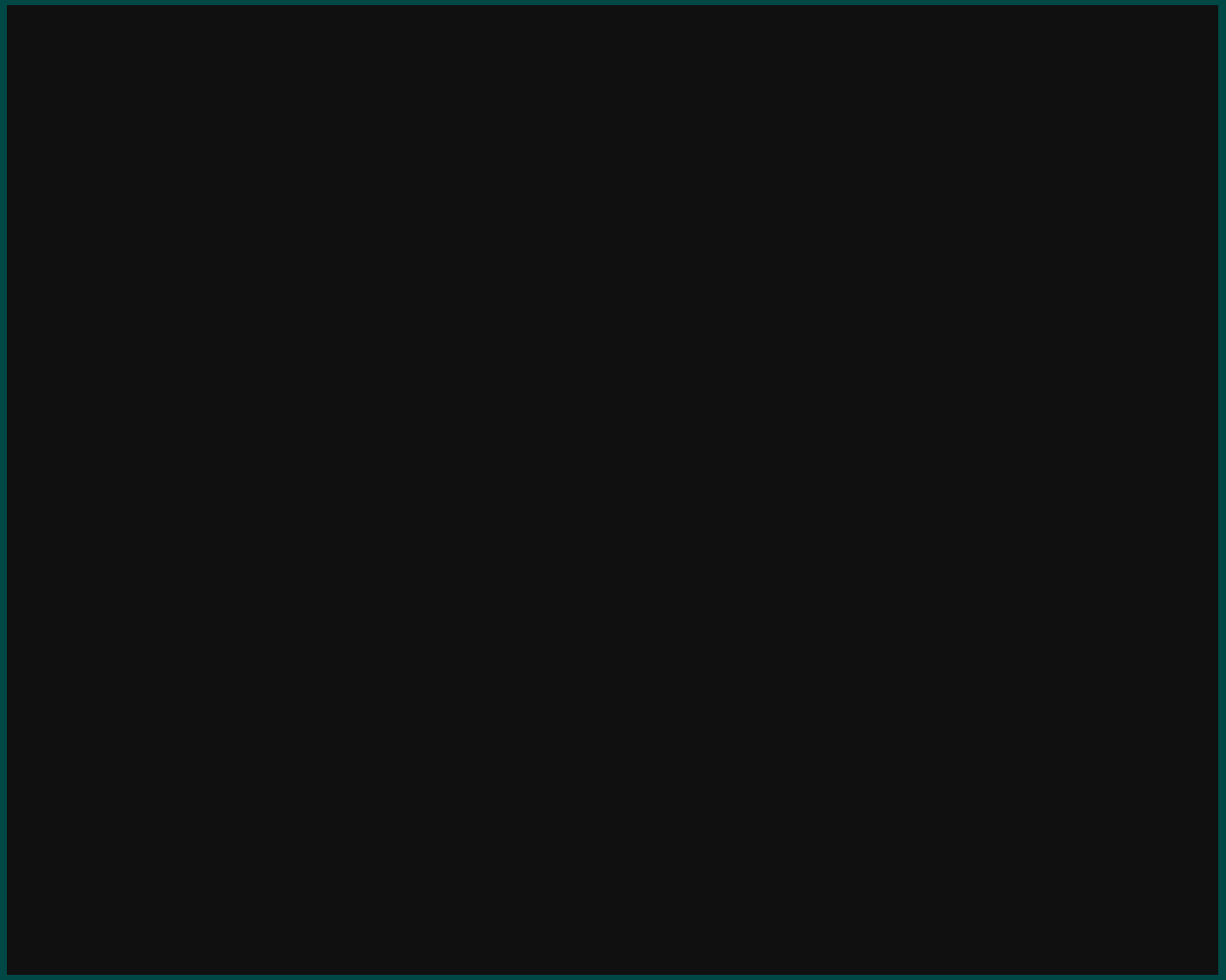
Colour video example 2

Blurred Video of Truck OT - MACH

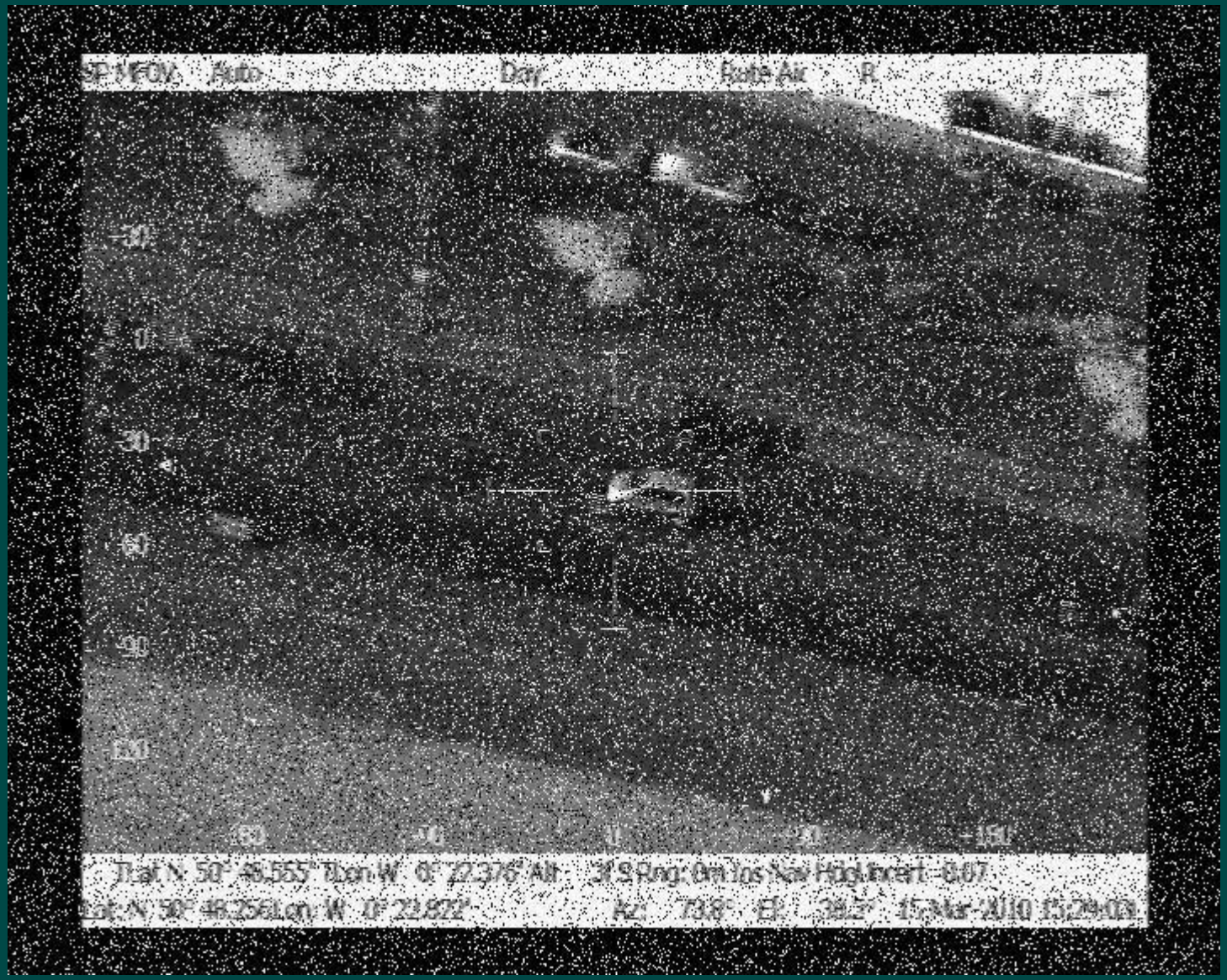
Gaussian blurring 7x7 kernel, sigma = 2.0

OT-MACH tracker results

Colour video example 3



Salt and pepper noise (45% noise) results



Salt and pepper noise (45% noise) results

Gaussian Noise SD=55 pixels, zero mean

Gaussian Noise SD=45, zero mean

Conclusions: Tracking

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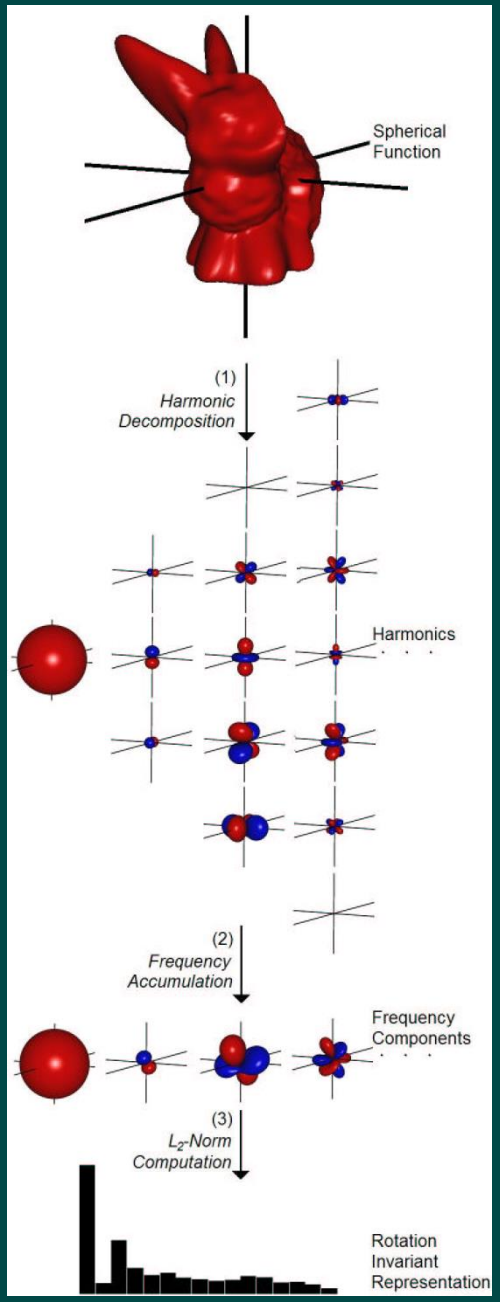
- Optimized robust real-time target tracker.
- The filter is dynamically updatable in run-time
- The improved active contour based filter initialisation and update allows us to maintain a strong and accurate correlation peak at the target location.
- Out performs the Kalman and particle filter
- Fast enough for smart camera’s or to be server based


Spherical
Function
(1)
Harmonic
Decomposition
Harmonics
(2)
Frequency
Accumulation
Frequency
Components
(3)
L_2-Norm
Computation
Rotation
Invariant
Representation

References

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2) PM Birch, R Young, D Budgett, C Chatwin, “Two-pixel computer-generated hologram with a zero-twist nematic liquid-crystal spatial light modulator,” Optics letters 25 (14), 1013-1015, 2000
3) P Birch, R Young, M Farsari, C Chatwin, D Budgett, “A comparison of the iterative Fourier transform method and evolutionary algorithms for the design of diffractive optical elements,” Optics and Lasers in engineering 33 (6), 439-448, 2000
4) P Birch, R Young, D Budgett, C Chatwin, “Dynamic complex wave-front modulation with an analog spatial light modulator,” Optics letters 26 (12), 920-922, 2001
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6) RKK Wang, L Shang, CR Chatwin, “Modified fringe-adjusted joint transform correlation to accommodate noise in the input scene,” Applied optics 35 (2), 286-296, 1996
7) P Birch, R Young, C Chatwin, M Farsari, D Budgett, J Richardson, “Fully complex optical modulation with an analogue ferroelectric liquid crystal spatial light modulator,” Optics communications 175 (4), 347-352, 2000
8) RCD Young, CR Chatwin, BF Scott, “High-speed hybrid optical/digital correlator system,” optical engineering 32 (10), 2608- 2615, 1993
9) PM Birch, R Young, D Budgett, C Chatwin, “Two-pixel computer-generated hologram with a zero-twist nematic liquid-crystalspatial light modulator,” Optics letters 25 (14), 1013-1015, 2000
10) GD Ward, IA Watson, DES Stewart-Tull, AC Wardlaw, CR Chatwin, “Inactivation of bacteria and yeasts on agar surfaces with high power Nd: YAG laser light,” Letters in applied microbiology 23 (3), 136-140, 1996
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13) RKK Wang, CR Chatwin, L Shang, “Synthetic discriminant function fringe-adjusted joint transform correlator,” Optical Engineering 34 (10), 2935-2944, 1995

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